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Performance Assessment Technology Development for Cleanup and Disposal of Hanford Defense Wastes

Prepared for the U.S. Department of Energy
Assistant Secretary for Defense Programs

Westinghouse Hanford Company P.O. Box 1970 Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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ABSTRACT

This report constitutes the strategy for identifying, adapting, improving, and using the technology needed to evaluate the long-term environmental consequences of actions proposed for remediation and disposal of radioactive and associated chemical wastes generated by defense-related activities at the U.S. Department of Energy's Hanford Site in Washington State. The objective of the strategy is to advance the technology sufficiently to do the analyses identified by the final environmental impact statement for disposal of Hanford Site defense wastes.*

*DOE, 1987, Disposal of Hanford Defense, High-Level, Transuranic, and Tank Wastes. Final Environmental Impact Statement, DOE/EIS-0113, vol. 1-3, U.S. Department of Energy, Washington, D.C.

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EXECUTIVE SUMMARY

This report constitutes the strategy for identifying, developing, and applying the technology needed to evaluate the long-term environmental consequences of actions proposed for remediation and disposal of radioactive and associated chemical wastes from defense-related activities at the U.S. Department of Energy's Hanford Site in Washington State. The technology that will be used to make the evaluations is termed "performance assessment." Performance assessment technology is dependent on the hierarchy of computer-encoded conceptual and mathematical models and assumptions used in the evaluation process to simulate the long-term performance of waste disposal options.

Such evaluations must determine how well the proposed waste cleanup and disposal actions can be expected to protect the environment. This question will be answered by the resolution of subordinate performance assessment issues identified in the Hanford Waste Management Technology Plan (DOE-RL 1987).*

The analytical capability resulting from completion of the work described in this report will be used to evaluate disposal of grouts, soils, and refuse with chemical, transuranic, or low-level radioactive contamination. The analytical capability that will be used to document the safe disposal of high-level radioactive waste is addressed by the Nevada Test Site Characterization Plan being generated in response to the Nuclear Waste Policy Act of 1983 (Public Law 97-425) as amended in 1987.

The plans of this report encompass developing computer-encoded mathematical models and a data base that is suitable for simulating performance of the proposed waste remediation and disposal systems with adequate confidence. Included is the description of work needed to address each performance assessment issue. To help fulfill the role of performance assessment in defining programmatic needs and setting priorities for data collection and analysis, plans are included in appendix A for assigning waste form and barrier functions, and allocating associated performance goals and required confidences. By this means, in conjunction with marginal utility cost-benefit analyses that are specific to each waste-form remediation and disposal program, the comparative merits of alternative designs can be evaluated, and site characterization or materials test data that may not be needed can be identified.

Plans for specific, quantitative assessments of the environmental consequences of each proposed disposal action, for each type of waste and waste form, are beyond the scope of this report. Consequently, the analytical framework established by this report will be complemented, as needed, by detailed plans for evaluating the performance of disposal options for specific waste forms. Completion of the technology development work described in this report is currently projected to require 6 years and the expenditure of approximately $5.6 million.

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*DOE-RL, 1987, Hanford Waste Management Technology Plan, DOE/RL 87-14, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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3.3.13 Task DCS-1.7.1--Develop or Modify Deterministic, Computer-Encoded Mathematical Model(s) for Simulating Contaminant Releases from Waste Forms

The work that comprises this task will be contingent on recommendations of the peer reviews of Task DCS-1.1.8 and approval of the technical program plans of Task DCS-1.1.6 (see fig. 4). This work includes developing or adapting computer codes, establishing benchmarks, calibration, verification, and validation. The objective of this task is to obtain a computer-encoded mathematical model(s) that adequately simulates the rates of release of contaminants from the defense wastes slated for remedial action or permanent disposal at the Hanford Site.

Such mathematical models are based on the governing processes of the conceptual model(s) of contaminant release. These processes must be simulated in terms of parametric equations based on accepted scientific principles. Most of the parametric equations portray a causal relationship of the type expressed by applying the laws of conservation of mass, momentum, and energy. However, in some cases, phenomenologically and (or) empirically based relationships may be used.

Achievement of adequate simulation capability is currently believed to require the ability to address conditions that will change during the next 10,000 yr, and to account for contaminant release mechanisms that will likely differ from waste form to waste form. More specifically, demonstration of adequacy probably will require that the computer-encoded model consider contaminant release rates dominated by molecular diffusion. Molecular diffusion, in turn, is controlled by transient concentration gradients and/or solubility limits. These controlling factors are specific to the chemical and physical characteristics of the waste forms and disposal sites, and chemical composition and physical characteristics of contaminants released from the waste forms.

The results of contaminant release simulations, in conjunction with output of the UNSAT-H (Fayer et al. 1986), UNSAT2 (Davis and Neuman 1983) or similar computer code (fig. 5), and site-specific data on hydraulic and geochemical properties of surficial sediments, will provide information for simulating contaminant transport in groundwater of the vadose and saturated zones. Transport simulations (fig. 5) will be by a variant of a computer code such as PORFLO (Runchal et al. 1985), SEMTRA (Baca et al. 1978), or TRACR3D (Travis 1984).

The computer code that has been used for analyses of contaminant releases from most Hanford Site waste forms is MINTEQ (Felmy et al. 1984; Peterson et al. 1987). However, other computer codes, such as EQ3/6 (Wolery 1979) and PHREEQE (Parkhurst et al. 1980), may be adapted for analyses of contaminant releases from liquids entrained in pore spaces of precipitated solids contained in single-shell tanks.

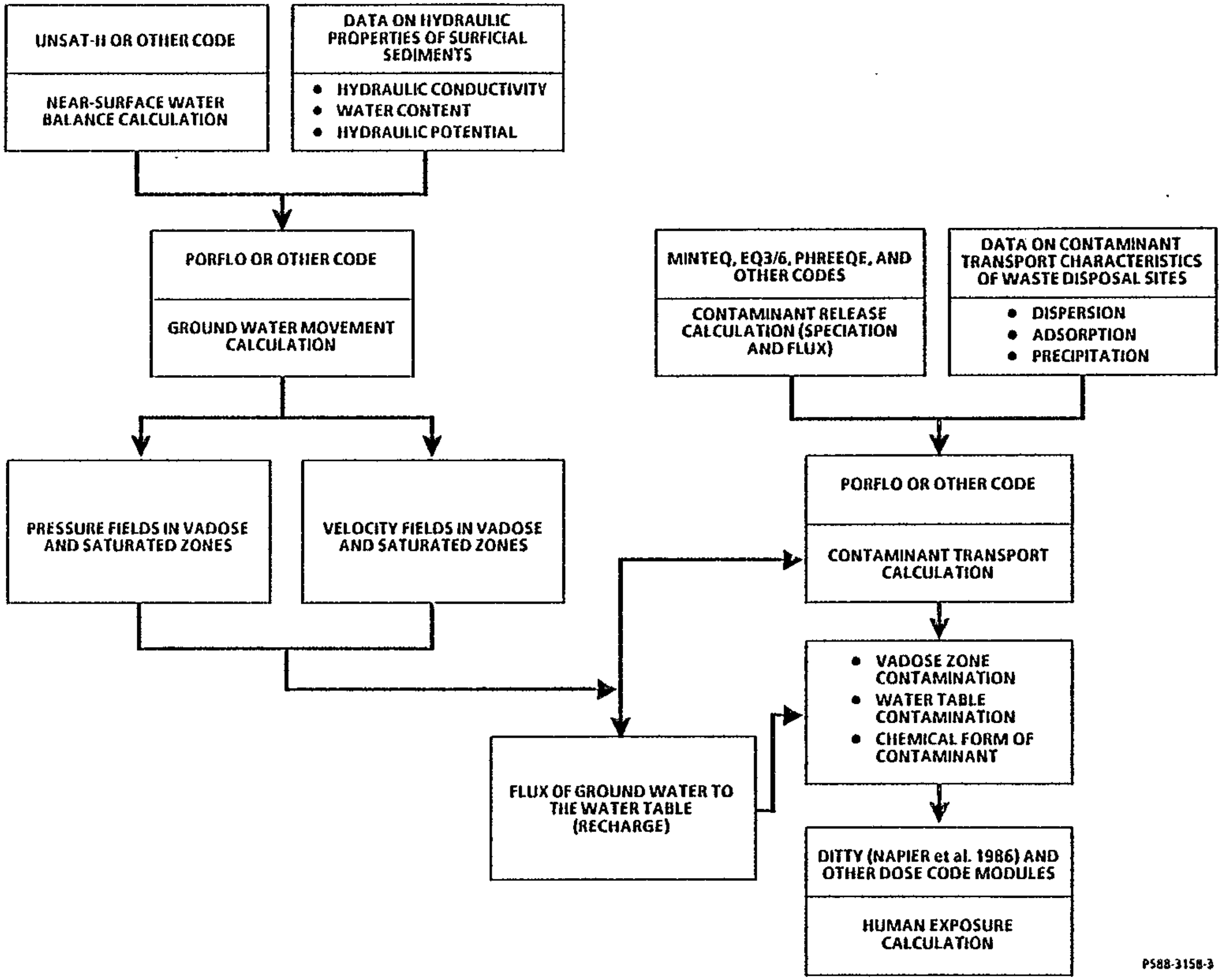

Figure 5. Examples of the Use of Computer Codes in Simulating Performance of Waste Remediation and Disposal Options.

3.3.9 Task DCS-1.1.4--Identify What Sensitivity Analyses are Needed

Sensitivity analyses will compare performance of specific portions of the waste disposal systems to their tentatively allocated performance goals. Identification of what sensitivity studies are needed will initially be based on examination of the results of performance assessments for the HDW-EIS (DOE 1987). Subsequent identification of needed sensitivity analyses will be based on the results of completed sensitivity studies, data collection activities, engineered barrier design changes, and peer reviews. Thus, the approach will be iterative to provide increasingly accurate results.

The sensitivity studies will consist of periodic analyses, using the controlled set of computer-encoded mathematical models and data, to evaluate quantitatively the sensitivity of contaminant release and migration to the values of parameters that describe the physical system and characterize its governing processes.

The objectives of identifying which parameters significantly affect system performance are to optimize designs of engineered barriers and focus data collection efforts on reducing uncertainties of parameter values that potentially have the largest effects on performance. These analyses can also help determine the maximum or minimum value of a parameter that is needed to achieve a performance goal allocated to a barrier or system component. Hence, the results of the analyses identified by this task will be a major consideration for barriers design, test planning, and simulation of system performance.

Several methods can be used to estimate sensitivity of performance to variations in parameter values. Alternatives include expert opinion, simulation by computer-encoded mathematical models, analytic solutions, laboratory testing, and field testing or observation. Because of the large spatial and temporal scales imposed in predicting system performance, laboratory experiments and field testing cannot be exclusively relied on to provide the required results. Analytic solutions can be found for simple contaminant transport problems, but are not feasible for more complex physical systems. Hence, a combination of expert technical opinion and computer simulations will be used. The conservatism of the simplifications and assumptions of these simulations will require extensive peer review and subsequent verification as additional information becomes available.

3.3.10 Task DCS-1.1.7--Identify What Performance Assessments are Required by Regulations and to Address Program Needs

(Task is to be performed by Westinghouse Hanford and includes performance assessments for remedial investigations and feasibility studies.)

3.3.11 Task DCS-1.1.8--Conduct and Document Peer Reviews of Planned and Completed Work

As shown in figure 4, peer reviews of work planned and completed to develop performance assessment technology will be needed at several stages of program completion. Peer reviews will be used to help determine if additional development of deterministic or probabilistic computer-encoded models is needed, and if the results of performance analyses indicate a need for reallocation of performance goals, and (or) collection of additional disposal-site data, and (or) changes in designs or materials of engineered barriers.

Peer reviews will be part of the process of computer code development, calibration, establishment of benchmarks, verification, and validation. Peer reviews will also judge the adequacy of the performance assessment data base and conceptual models, and the results of waste-form-specific performance assessments.

Avoidance of potential conflicts of interest requires that some of the technical peer reviews be performed by scientists and engineers who are not members of the organizations that completed the work being reviewed. The education and professional experience of reviewers, with specific reference to the work reviewed, must be documented in writing before initiation of their reviews.

3.3.12 Task DCS-1.1.6--Issue Plans for Improving Performance Assessment Data Base and Analytical Capabilities

The results of peer reviews will be used to make decisions on whether additional simulation capabilities and data base enhancements are needed and, if so, what that work should be. If additional work is recommended, detailed plans will be written by the organization or subcontractor that will be performing the work and submitted to Westinghouse Hanford for concurrence before initiation of the work.

The plans will be submitted annually in the form of a Technical Program Plan. They will include (1) detailed technical description of the work to be performed, (2) rationale for doing the work in terms of specific ties to the information need identified by allocating performance goals and assigning needed confidences, (3) impacts, if any, on other program activities, (4) completion schedule, and (5) estimated costs.

Documentation of completion of this task is expected to be in the form of publicly available reports. These reports will, at a minimum, consist of a technical manual, a report on the results of verification and benchmark tests, a user's guide, and a report on the results of calibration and validation testing for each code.

3.3.14 Task DCS-1.8.1--Develop or Modify Deterministic, Computer-Encoded Mathematical Model(s) for Simulating Groundwater Movement

As was the case for Task DCS-1.7.1, the specific work of this task will depend on the results of independent peer reviews and approval of updated technical program plans. This task is comprised of developing or adapting computer codes and establishing code benchmarks, calibration, verification, and validation. The objective is to obtain a computer-encoded model(s) that adequately predicts the movement of water in the vadose and saturated groundwater zones of heterogeneous, hydrologically anisotropic surficial sediments of the Hanford Site.

Data on hydraulic properties of surficial sediments and the results of near-surface water-balance calculations will be used by a variant of a code such as UNSAT-H, UNSAT2, PORFLO, SEMTRA, or TRACR3D to simulate water movement in the vadose and saturated groundwater zones (table 1; also see fig. 5). The mathematical representation(s) of groundwater movement will be coupled with a mathematical representation(s) of contaminant transport (section 3.3.15) to simulate the effects of waste disposal and remediation options.

Table 1. Groundwater Flow and Contaminant Transport Computer Codes.

Computer code	Type	Modeling capabilities
UNSAT-H	Finite difference	One-dimensional, unsaturated groundwater flow
UNSAT2	Finite element	Two-dimensional, unsaturated groundwater flow
PORFLO-3*	Integrated finite difference	Three-dimensional saturated groundwater flow, heat transfer, and contaminant transport
SEMTRA	Finite element	Two-dimensional, saturated groundwater flow and heat transfer
TRACR3D	Integrated finite difference	Three-dimensional, unsaturated groundwater flow and contaminant transport

*In FY 1988, capability is being added to model three-dimensional groundwater flow, heat transfer, and contaminant transport for unsaturated conditions.

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Simulations of groundwater movement in the above context must consider the following at yet-to-be-determined levels of detail:

- How geologic heterogeneity affects groundwater movement
- The potential for vertical and lateral groundwater movement through and under an engineered barrier
- The relationships of advective and diffusive mechanisms of contaminant transport to moisture contents and rates of water infiltration
- Changes in the near-surface water balance, water table elevation, and discharge areas
- How nonisothermal conditions locally affect groundwater movement.

Completion of this task is expected to be documented by publicly available reports consisting of a technical manual, a report on the results of verification and benchmark tests, a user's guide, and a report on the results of calibration and validation testing for each code.

3.3.15 Task DCS-1.9.1--Develop or Modify Deterministic, Computer-Encoded Mathematical Model(s) for Simulating Contaminant Transport in Groundwater

Simulating transport of contaminants from Hanford Site defense wastes by vadose and saturated zone groundwater requires information of four types (see fig. 5): (1) hydraulic pressure fields, (2) velocity fields calculated by the computer code that simulates groundwater movement, (3) chemical form of contaminant and the contaminant flux determined by the computer code that simulates contaminant releases, and (4) extensive data on contaminant transport characteristics of the proposed disposal sites.

Many interrelated factors determine contaminant transport. If system performance is found to be sensitive to a specific factor or set of interrelated factors, these factors will have to be addressed by the computer-encoded model used to simulate contaminant transport. Among such factors are the following:

- Ion exchange by clays and zeolites of surficial sediments
- Chemical form of contaminant
- Distribution coefficients of contaminants
- Sorption-desorption kinetics
- Precipitation and solubility as a function of oxidation potential, pH, and temperature

- Buffering capacity of surficial sediments
- Groundwater chemistry
- Formation of inorganic ligands and organic complexes
- Filtering of suspended contaminant particles as a function of sediment grain sizes and size distributions.

The specific work of this task, like that of Tasks DCS-1.7.1 and DCS-1.8.1, will be contingent on the recommendations of peer reviewers and approval of updates of technical program plans (see fig. 4). The equations that express the processes of contaminant transport will be coupled with those describing groundwater movement, as part of a variant of PORFLO or a similar code. Elements of the work include developing or modifying computer codes to address the above considerations, and establishing code benchmarks, verification, calibration, and validation.

Documentation of completion of this task is expected to be by publicly available reports. At a minimum, these reports will consist of a technical manual, a report on the results of verification and benchmark tests, a user's guide, and a report on the results of calibration and validation testing for each code.

3.3.16 Task DCS-1.10.1--Develop or Modify a Computer Code to Simulate Human Exposures

(A documented update of the DITTY computer code and its coupled modules for calculating radiological exposures is scheduled for completion by PNL in 1988.)

3.3.17 Task DCS-1.11.1--Modify Deterministic, Computer-Encoded Mathematical Models for Stochastic Analyses

The computer-encoded models that will be developed by completion of Tasks DCS-1.7.1 through DCS-1.10.1 can be employed to simulate performance for discrete values of input parameters. However, regulatory agencies may require that assessments of long-term effects of radioactive and hazardous chemical wastes incorporate uncertainties. One means of expressing these uncertainties could be as a cumulative probability distribution of contaminant releases to the accessible environment.

If this requirement is applied to defense-related wastes that are being evaluated for waste cleanup or disposal actions, development of Monte Carlo or finite-order stochastic modeling techniques may be needed. In this event, probabilistic versions of one or more of the computer codes of Tasks DCS-1.7.1 through DCS-1.10.1 will be developed. Whether such simulations are needed will be determined in consultation with appropriate regulatory agencies. The specific kinds of technology development work that are needed, if any, will be recommended by independent peer reviewers (see section 3.3.11, Task DCS-1.1.8).

If development of stochastic models is deemed to be necessary, detailed plans for completing the work will be written by the organization or subcontractor that will perform the work. The plans will be written in accordance with the provisions of Task DCS-1.1.6 (see section 3.3.12).

If initiated, this task would include development of probabilistic codes, establishing benchmarks, calibration, verification, and validation. Documentation of task completion is expected to be by publicly available reports: a technical manual, a report on the results of verification and benchmark tests, a user's guide, and a report on the results of calibration and validation testing for each code.

3.3.18 Task DCS-1.11.2--Obtain Probability Distributions for Stochastic-Model Input-Parameter Data

If computer-encoded mathematical models are developed that account for uncertainties, the uncertainties associated with various values of modeling parameters will have to be quantified. Not all uncertainties are objectively quantifiable; disposal sites cannot be characterized with complete certainty. Those uncertainties that are not objectively quantifiable will have to be evaluated through probability-encoded, subjective expert judgment.

For the purposes of sensitivity analyses, probability distributions of parameter values often can be assigned using conservative assumptions and conceptual model simplifications. In assessing system performance for documenting compliance with regulations (as compared to assessing performance for evaluating sensitivity), the probability distributions will be based on empirically derived, site-specific information whenever possible.

Scenarios that can be shown not to significantly change the probability distribution of contaminant releases to the accessible environment will not be included in detailed performance assessments. If scenarios are determined by sensitivity analyses to have significant effects on contaminant releases (e.g., >10% of the total), those predicted releases will be analyzed in detail. The results will be incorporated into a probability distribution function that depicts probabilities of exceeding a specific regulatory limit (e.g., fig. 6).

Stochastic simulation of performance, given the conditions of unanticipated processes and events, will require information on probability distributions of parameters used in the models, the probability of occurrence of the event or process, and the joint or conditional probabilities of related processes and conditions.

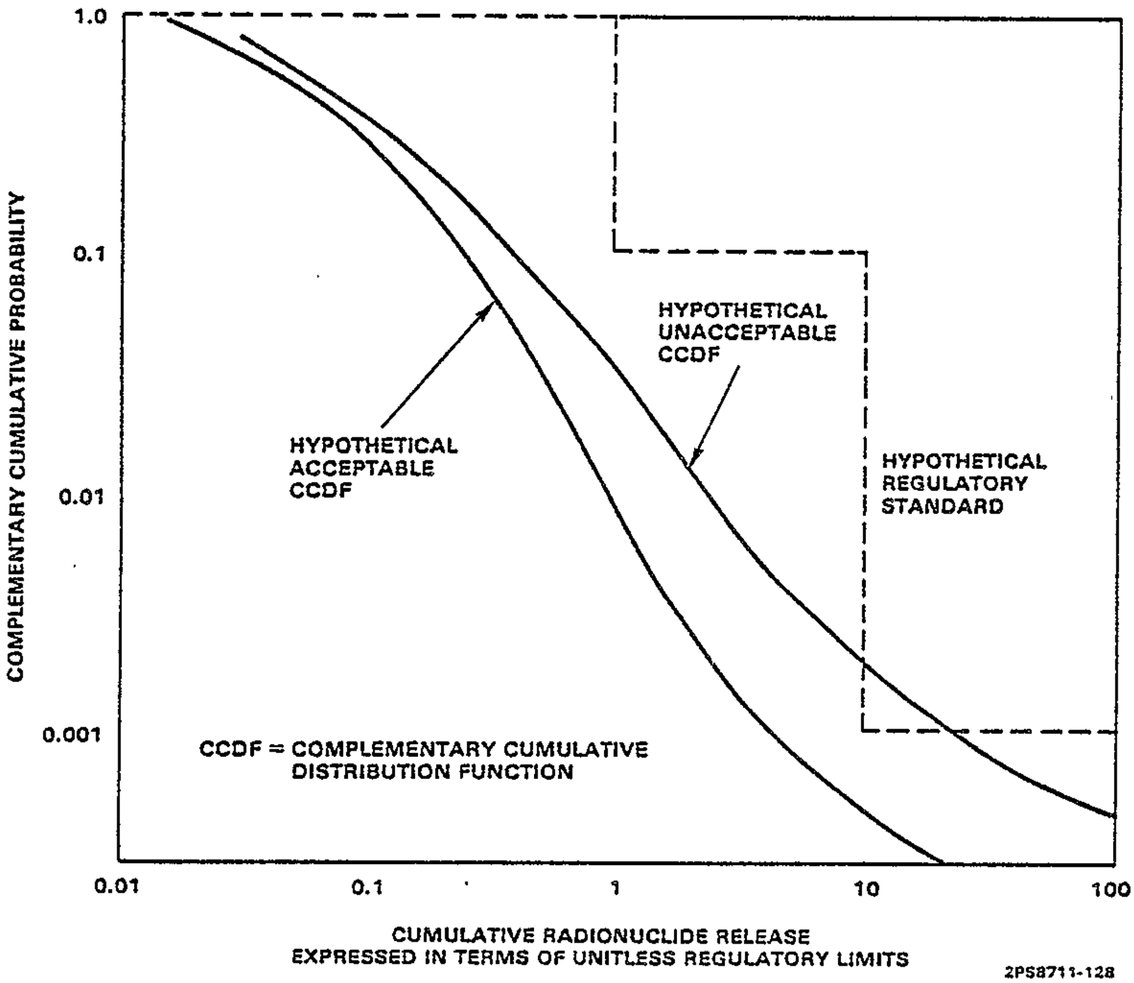

Figure 6. Example of Hypothetical Complementary Cumulative Probability Distributions.

Completion of this task will be documented by a demonstrably operable data base that contains probability distributions of all stochastic modeling parameters, and occurrence probabilities of all scenarios.

3.3.19 Task DCS-1.7.2--Conduct Sensitivity and/or Performance Assessment Analyses of Contaminant Releases

(Task is to be performed by waste-specific programs managed by Westinghouse Hanford.)

Programmatic needs for evaluating the sensitivity of performance to factors affecting releases of contaminants from the various forms of Hanford Site defense wastes initially will be identified based on results reported in the HDW-EIS (DOE 1987). Subsequent identification of analytical needs will be based on the results of sensitivity analyses as they are completed. The nature, methods, objectives, and applications of sensitivity analyses are described in section 3.3.9.

Performance assessments will be conducted in a manner very similar to that of sensitivity analyses. The principal differences are in purpose and the nature of input data. Assessments of disposal or remediation system performance will use the best available, test-based estimates of parameter values, ranges, and probability distributions to document compliance with applicable regulations. In contrast, sensitivity studies will be designed to help guide simulation model development, engineered design, and collection of test data. Sensitivity analyses will use values, ranges, or distributions of modeling parameters that typically will be assigned based on conservative assumptions and sparse data, because definitive test data will not yet be available.

The results of sensitivity studies will undergo peer review and technical evaluation to help determine whether the allocations of performance goals should be refined, designs of engineered barriers should be altered, or if collection of additional site characterization information is needed. The results of performance assessments will also undergo peer review and technical evaluation. In these cases, the purpose of the reviews will be to determine whether the proposed waste cleanup or disposal actions are reasonably likely to comply with environmental protection standards, and if the analysis is valid.

3.3.20 Task DCS-1.8.2--Conduct Sensitivity and/or Performance Assessment Analyses of Groundwater Movement for Specific Waste Disposal Options

(Analyses are to be completed by waste-specific disposal programs managed by Westinghouse Hanford; see section 3.3.19.)

3.3.21 Task DCS-1.9.2--Conduct Sensitivity and/or Performance Assessment Analyses of Contaminant Transport for Specific Waste Disposal Options

(Analyses are to be completed by waste-specific disposal programs managed by Westinghouse Hanford; see section 3.3.19.)

3.3.22 Task DCS-1.10.2--Calculate Human Exposures Resulting from Proposed Waste Disposal Actions

(Task is to be completed by waste-specific disposal programs managed by Westinghouse Hanford.)

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4.0 SCHEDULE AND BUDGET FOR TASK COMPLETION

The time and expenditure of money needed to complete the performance assessment technology development program are estimated in table 2. The tasks of table 2 are listed in order of projected need and priority (also see fig. 4). The table is based on current information on cummulative costs of task completion. These costs are projected to total approximately $5.6 M. The written reports that will document progress and completion of each task are specified in the table in terms of the type of report required and the date of its required completion. Estimated expenditures are given on a fiscal year basis. Shading depicts projection of when the work will be performed. Task numbers are cross-referenced to cost account numbers for FY 1988. The key assumptions and premises on which the table are based are noted at the end of the table.

As explained in earlier sections of this report, the need, relative cost, and level of effort for some tasks identified in the table are dependent on decisions that are yet to be made and that cannot be made until precursory data collection and analysis activities have been completed (see fig. 1 and 4). Consequently, this table will be revised annually during the life of the program to update schedules and reflect the current level of funding available.

Table 2. Schedule, Budget, and Estimated Cost of Task Completion. (sheet 1 of 3)

TASK NUMBER / FY 1988 COST ACCOUNT	TASK NAME / ESTIMATED WORK CONTENT	FISCAL YEAR AND QUARTER (DOLLARS IN THOUSANDS)																							
		1988				1989				1990				1991				1992				1993			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1.1.1	ESTABLISH ISSUES HIERARCHY		▲PR		▲L																				
1EREOA	(DRAFT COMPLETED; PEER REVIEW FUNDED IN FY 1988)	10																							
1.1.2	DEVELOP PERFORMANCE ASSESSMENT STRATEGY		▲PR		▲L																				
1EREOA	(DRAFT COMPLETED; PEER REVIEW FUNDED IN FY 1988)	30																							
1.12.1	DEVELOP A QUALITY ASSURANCE PLAN				▲L																				
1EREOA, 1ERE020A	(UPDATE AND PEER REVIEW FUNDED IN FY 1988)	10, 10																							
1.12.2	ISSUE QUALITY ASSURANCE IMPLEMENTATION PROCEDURE				▲L																				
1EREOA, 1ERE020A	(UPDATE AND PEER REVIEW FUNDED IN FY 1988)	10, 10																							
1.1.3	DEVELOP CONCEPTUAL MODELS							▲PR				▲PR				▲PR				▲PR				▲PR	
	(UNFUNDED BY PERFORMANCE ASSESSMENT IN FY 1988)					150				150				150				150				75			
1.6.1	ESTABLISH DATA-ENTRY CRITERIA FOR DATA BASE			▲L																					
1EREOA, 1ERE020A	(PEER REVIEW FUNDED IN FY 1988)	20, 10																							
1.6.2	ESTABLISH AND MAINTAIN DATA BASE					▲PQ				▲PQ				▲PQ				▲PQ				▲PQ			PQ▲
1ERE020A, 1ERE020E, -020F	(INCLUDES RECHARGE AND HYDRAULIC CONDUCTIVITY DATA COLLECTION)	40, 186, 125				250				250				250				250				250			
1.1.5	ALLOCATE PERFORMANCE GOALS AND CONFIDENCES																								
	(TO BE FUNDED BY CRITERIA AND STANDARDS PROGRAM)																								
1.1.4	IDENTIFY SENSITIVITY ANALYSES						▲L				▲L				▲L				▲L						
	(UNFUNDED BY PERFORMANCE ASSESSMENT IN FY 1988)					30				30				30				30							

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Table 2. Schedule, Budget, and Estimated Cost of Task Completion. (sheet 2 of 3)

TASK NUMBER / FY 1988 COST ACCOUNT	TASK NAME / ESTIMATED WORK CONTENT	FISCAL YEAR AND QUARTER (DOLLARS IN THOUSANDS) 1988 (1, 2, 3, 4)	1989 (1, 2, 3, 4)	1990 (1, 2, 3, 4)	1991 (1, 2, 3, 4)	1992 (1, 2, 3, 4)	1993 (1, 2, 3, 4)
1.1.7	IDENTIFY PERFORMANCE ASSESSMENT ANALYSES					L	L
	(UNFUNDED BY PERFORMANCE ASSESSMENT IN FY 1988)					30	30
1.1.2	TECHNICAL PROGRAM MANAGEMENT AND CONDUCT AND DOCUMENT PEER REVIEWS	L	L, L	L, L	L, L	L, L	L, L, L
1EREOA		377	300	300	250	250	200
1.1.6	ISSUE TECHNICAL PROGRAM PLANS		PR	PR	PR	PR	PR, PR
1EREOA, 1ERE020A		10, 10	20	20	20	20	20
1.7.1	DEVELOP CONTAMINANT RELEASE MODEL(S)			PR	PR		PR
	(UNFUNDED BY PERFORMANCE ASSESSMENT IN FY 1988)		100	150	100	100	
1.8.1	DEVELOP GROUNDWATER MOVEMENT MODEL(S)		PR	PR	PR		PR
1ERE020C, 1ERE020A, 1EREOA	(UNFUNDED IN FY 1988 EXCEPT FOR DEVELOPMENT OF UNSAT-H MODEL)	150, 20, 10	150	150	150	150	
1.9.1	DEVELOP CONTAMINANT TRANSPORT MODEL(S)						
	(INCLUDED IN 1.8.1)						
1.10.1	DEVELOP HUMAN EXPOSURE MODEL						
	(UNFUNDED BY PERFORMANCE ASSESSMENT; WILL BE COMPLETED IN JANUARY 1988)						
1.11.1	MODIFY MODELS FOR STOCHASTIC ANALYSES					PR	PR, PR
	(UNFUNDED BY PERFORMANCE ASSESSMENT IN FY 1988; MAY NOT BE REQUIRED)						
1.11.2	OBTAIN PROBABILITY DISTRIBUTIONS OF DATA					PR	PR, PR
	(UNFUNDED BY PERFORMANCE ASSESSMENT IN FY 1988; MAY NOT BE REQUIRED)						

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Table 2. Schedule, Budget, and Estimated Cost of Task Completion. (sheet 3 of 3)

TASK NUMBER / FY 1988 COST ACCOUNT	TASK NAME / ESTIMATED WORK CONTENT	1988 (Q1–Q4)	1989 (Q1–Q4)	1990 (Q1–Q4)	1991 (Q1–Q4)	1992 (Q1–Q4)	1993 (Q1–Q4)
1.7.2	CONDUCT ANALYSES OF CONTAMINANT RELEASE		▲ PR	▲ PR	▲ PR	▲ PR	▲ PR
(SEE HWMTP)	(TO BE COMPLETED BY WASTE-SPECIFIC PROGRAMS)						
1.8.2	CONDUCT ANALYSES OF GROUNDWATER MOVEMENT		▲ L	▲ L	▲ L	▲ L	▲ L
(SEE HWMTP)	(TO BE COMPLETED BY WASTE-SPECIFIC PROGRAMS)						
1.9.2	CONDUCT ANALYSES OF CONTAMINANT TRANSPORT						
(SEE HWMTP)	(INCLUDED IN 1.8.2)						
1.10.2	CALCULATE HUMAN EXPOSURES			▲ L	▲ L	▲ L	PR ▲
	(TO BE COMPLETED BY OTHER PROGRAMS MANAGED BY WHC)			100	100	100	100
	TOTAL COST OF PROGRAM (ANNUALIZED BASIS)	1,038	1,050	1,050	950	930	575

FISCAL YEAR AND QUARTER (DOLLARS IN THOUSANDS)

NOTE:
1. APPROVED BUDGET SHOWN FOR FY 1988; ESTIMATED COSTS SHOWN FOR FY 1989 THROUGH 1993; ALL COSTS ARE EXPRESSED IN TERMS OF THOUSANDS OF DOLLARS.
2. SEE THE HANFORD WASTE MANAGEMENT TECHNICAL PLAN (DOE 1987) FOR DETAILS ON MANPOWER LOADING.
3. FISCAL YEAR ENDS SEPTEMBER 30.
4. DELIVERABLES (▲) ARE SPECIFIED IN SECTION 3.3 OF THIS REPORT. PR = PUBLICLY AVAILABLE REPORT; L = LETTER REPORT; P = PROCEDURE; PO = PRINTOUT.
5. TASKS ARE LISTED IN APPROXIMATE ORDER OF INITIATION; SHADING INDICATES QUARTER IN WHICH WORK ON TASK IS SCHEDULED.
6. SCHEDULE ASSUMES THAT INITIAL PERFORMANCE ASSESSMENTS IN SUPPORT OF COMPLIANCE DOCUMENTATION WILL BE NEEDED BY THE END OF FY 1993.
7. HWMTP = HANFORD WASTE MANAGEMENT TECHNICAL PLAN (DOE 1987).

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5.0 DEFINITIONS OF KEY TECHNICAL TERMS

Accessible Environment--The atmosphere, land surface, surface waters, ocean, and all of the biosphere and its contained groundwater that is beyond the controlled area.

Barriers--Physical and (or) chemical features of a waste disposal system whose intended function is to contain the wastes or to isolate the wastes from the accessible environment.

Benchmark--Comparison of the computational results of a specific computer code with the results of a reference computer code used to analyze the same or comparable problem.

Computer Code--A sequence of computer instructions to perform the operations specified by the numerical model of a system.

Conceptual Model--The quantitative and qualitative description of the physical characteristics and governing processes of a system or subsystem.

Controlled Area--Any specific region of the Hanford Site into which entry by personnel is regulated by physical barrier and (or) procedure.

Mathematical Model--A mathematical representation of a process, component, or system.

Numerical Method--A procedure for solving a problem primarily by a sequence of arithmetic operations.

Parameter--In the context of this report, a physical or chemical property whose value helps determine the characteristics of a waste disposal system.

Performance Allocation--Assignment of goals or limits of acceptability for performance, and confidence required in achieving those goals, to a system and its constituent subsystems, components, and parameters, such that if the goals are achieved, the system will protect the environment and comply with applicable governmental regulations.

Performance Assessment--Prediction of the behavior of a disposal action in terms of the containment and isolation of contaminants, for purposes of determining if the action will protect the environment and comply with governmental regulations.

Reference Computer Code--A computer code whose characteristics are well known through documented verification and validation.

Sensitivity Analysis--Quantitative determination of how changes in the values of parameters or assumptions affect performance of the system, subsystem, or barrier being evaluated. Sensitivity analyses are conducted to identify programmatic needs and priorities.

Validation--Comparison of the computational results of a specific application of a mathematical model with empirically derived data or information, for the purpose of demonstrating that the results correctly represent the processes and conditions that the model purports to simulate.

Verification--Testing of a specific computer code to demonstrate that it correctly solves, within limits for each parameter employed, the mathematical problem defined by the model.

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APPENDIX A

GUIDANCE FOR PERFORMANCE ALLOCATION

GUIDANCE FOR PERFORMANCE ALLOCATION

This appendix describes a means that can be used for documenting the relationships between performance assessment issues (see chapter 2.0) and work whose completion will be needed to help resolve those issues and ensure adequate protection of the environment. The purpose of this appendix is to present a vehicle for conveying guidance, based on results of preliminary performance assessments, performance sensitivity analyses, and expert technical judgment, to engineers designing barriers to contaminant release and transport, and scientists collecting remediation or disposal site data.

USE OF THE ISSUES RESOLUTION STRATEGY

Performance issues (see chapter 2.0) will be used as a basis for identifying activities needed to demonstrate that the waste disposal actions will have acceptable long-term environmental consequences. Because performance issues are derived from applicable regulations and other waste disposal requirements, resolution of performance issues requires work to be done to document compliance with those regulations and requirements. The approach shown in figure A-1 will be used to develop plans for resolving technical questions. The approach will apply to questions of remediation or disposal-site characterization, barrier design engineering, and system performance.

Performance allocation is an integral part of the issues resolution strategy. The approach to issues-related performance allocation is described in the following sections.

SCOPE, CONTENT, AND USE OF ISSUES

Resolution of performance issues will be the vehicle for using the results of assessments of remediation or disposal system performance to guide site characterization, design engineering, and performance assessment activities. An issues heirarchy will be used to identify all questions that need to be addressed by each waste remediation and disposal program. The heirarchy will be developed such that relevant questions which are not stated in the heirarchy, but that may be asked, will be covered in a general way by one or more issues. All work initiated for remedial actions or disposal of the wastes will thus be responsive in an identifiable way to specific issues in the heirarchy.

The issues in the issues heirarchy will be used as an organizing principle for the preparation of all technical program planning and reporting documents. The format of these documents will reflect the issues being addressed. For each issue, information needs will be identified. These needs are the information that is judged to be necessary and sufficient for the issue to be resolved for a specific waste form, remedial action, waste disposal method, or disposal site.

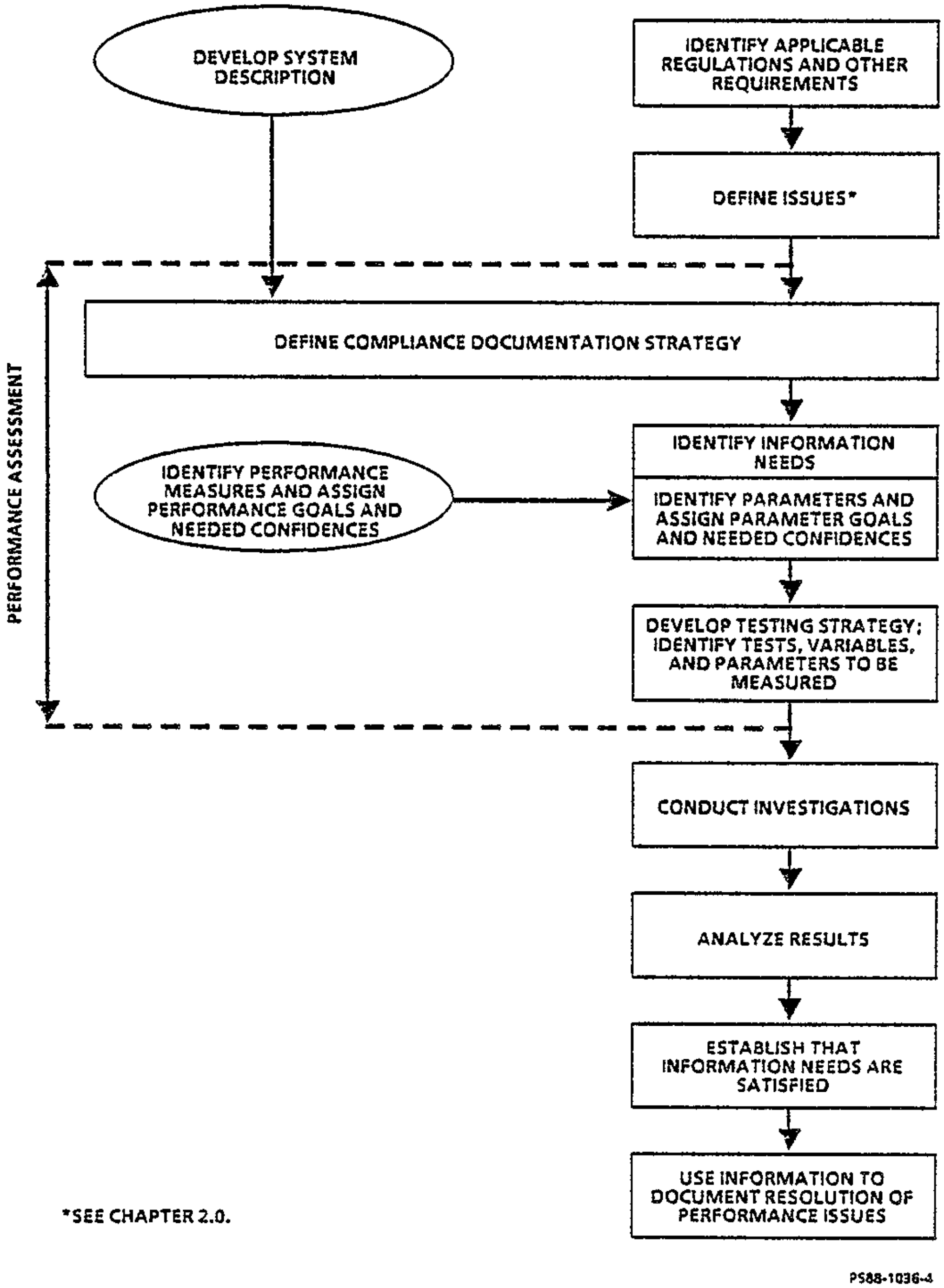

Figure A-1. Strategy for Resolving Performance Issues.

GUIDANCE FOR PERFORMANCE ALLOCATION

Performance allocation (see chapter 5.0 for definition) will specify the following for each remedial or disposal action.

1. The barriers that will be primarily relied on to retard release and transport of contaminants.

2. The barriers, if any, that are expected to function as secondary or redundant barriers, or barriers held in reserve.

3. The performance goal that the barrier is expected to achieve.

4. The confidence that is needed to achieve that performance goal.

Performance allocation will specify the following for each quantity to be measured by a testing program.

1. A performance goal.

2. The confidence that is needed to achieve the goal by means of the proposed or ongoing test or data collection program.

Performance goals may change; they are not regulatory criteria or standards that must, by statute, be complied with. Rather, they are an engineering tool by which the work needed to document compliance can be managed and guided. The goals are to be chosen such that, if achieved, they will demonstrate that the goals for the overall system performance will be achieved.

The confidence associated with a performance goal expresses a judgment of how certain a scientist or engineer must be of achieving that goal in order to demonstrate reasonable assurance of compliance with regulatory standards. It may be a statistically derived confidence level or confidence interval. More often, however, it will not be derived in a statistically rigorous way, and will not even be stated in terms of statistical parameters. When no rigorous or semi-quantitative statement is possible, it may be assigned by expert judgement or it may be stated as high, medium, or low, provided that these terms are adequately defined.

Performance allocation consists of a series of steps. A simple way to visualize these steps is presented in table A-1. The table lists the steps as the headings of columns. The performance allocation process consists of filling in the columns, as explained in the text that follows.

The first three steps are part of the overall compliance documentation strategy; they are the identification of potential barriers. Completion of these steps must precede assignment of performance goals and indicators of confidence. The remaining six steps are the actual allocation of performance goals and needed confidences.

Table A-1. Information Entry Form for Completing the Steps of Performance Allocation.

Compliance strategy			Performance allocation											
Step 1	Step 2	Step 3	Step 4	Step 5		Step 6			Step 7		Step 8		Step 9
Disposal system performance requirements (Actual requirements are yet to be determined)	Barriers to contaminant release and transport	Compliance approach (From step 3, part 3 of table A-3)	Performance measures	Performance goals and confidences		Parameter needs			Test definitions		Evaluation of test plans		Test integration
				Value	Confidence	Parameter	Range	Confidence	Measured parameter	Precision and accuracy	Value	Confidence	

PST88-3158-A1

Step 1: Performance Requirements

In this column of table A-1, the regulatory performance standards are listed. These standards can be stated either as numerical or non-numerical requirements for such criteria as groundwater protection, individual protection, and releases of contaminants to the accessible environment.

Step 2: Potential Barriers to Contaminant Release and Transport

The barriers that are potentially available to comply with the performance standards of step 1 are identified in this step. For example, compliance with a specific standard may be achieved by relying on barriers associated with the waste form, a second standard by relying on the waste form plus other barriers of the engineered subsystem, a third standard by relying on the natural barriers between the engineered subsystem and the accessible environment, and a fourth by relying on all barriers of the entire waste disposal system. In step 2, no selections are made from the potential barriers. They are simply listed for selection in step 3.

Step 3: Compliance Approach

Step 3 defines the approach for complying with each regulatory performance standard. It consists of deciding which of the potential barriers and processes will be used to show compliance with standards. The approach includes the following three parts.

Part 1. For each performance standard, the barriers and their components that will be relied on to show compliance of the system with the applicable standards are selected from the list of step 2. Some of these may be specified as redundant or secondary barriers; i.e., barriers to be held in reserve.

Part 2. For each selection of part 1, the function(s) that the barrier is expected to perform in complying with the performance standard are listed. Then, all processes and conditions likely to occur in the barrier are identified. These are the processes and conditions that determine whether the barrier will satisfactorily perform its expected functions.

Part 3. Of the processes and conditions that are identified in part 2, only those that will be accounted for in documenting compliance with the applicable standards are listed.

As an example, suppose that step 2 lists all of the engineered, natural, and institutional barriers that are available to comply with the performance standards. In part 1 of step 3, a choice might be made to rely on some of the engineered, some of the natural, and all of the institutional barriers.

An example of how the choice might be made is presented in table A-2. For each barrier chosen (and designated by the word "yes" in table A-2), the functions that the barrier is expected to perform and the processes that occur in it are listed. Then, selections are made from this list that will be used in showing compliance with regulatory standards. Table A-3 shows examples of these choices.

The choices made in step 3 set up the remainder of the allocation process and the overall compliance strategy. Although they can be modified as work on the remediation or disposal program proceeds, they should be chosen carefully. If subsequent data collection and analysis demonstrate that some of the available barriers can reasonably be omitted, the testing program and the compliance documentation strategy may be significantly simplified. However, it would be unwise to omit, at this early stage, any barriers that are likely to be needed eventually.

In some cases, it may be important for the choices to reflect intentions not only of complying with the regulations for expected conditions, but also for complying with them for unexpected (but credible) disruptive conditions that may occur in the future. Therefore, these choices must anticipate the scenario analyses that will be performed as part of the compliance documentation. A prudent approach to step 3 will require that a decision be made on what barriers will likely be relied on for both expected and unexpected conditions.

The basis for making the initial choices in step 3 will probably be the preliminary performance assessments and other bounding sensitivity studies that have already been completed. An update of step 3 will likely be necessary if revisions to the initial performance allocation are made.

Step 4: Performance Measures

With the completion of step 3, the compliance documentation strategy is in place and the allocation process can progress toward assigning performance goals and needed confidences. In step 4, the terms in which to express the performance goals that are chosen in later steps are determined. In other words, performance measures are identified.

For each function listed in step 3, a performance measure must be chosen; i.e., a physical quantity that indicates the means by which a function is performed. This quantity may be either a measurable entity or a dependent variable. For example, the function chosen in the first example for step 3 is "barrier to groundwater movement to the accessible environment." A measure of performance for this function could be hydraulic conductivity.

Table A-2. Example of Allocation Step 2 and Step 3, Part 1.

Step 2	Step 3, part 1
Barriers that could be relied on for protection of the environment	Barriers chosen for protection of the environment
1. Engineered barriers	Yes
a. Waste form	Yes
b. Recharge barriers	Yes
2. Natural barriers	Yes
a. Above waste	Yes
b. Below waste	No
3. Institutional barriers	Yes

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Table A-3. Example of Allocation Step 3, Parts 1 Through 3.

Step 3, part 1	Step 3, part 2		Step 3, part 3
Barriers chosen for protection of the environment	Function	Processes	Barriers chosen for protection of the environment
2. Natural barriers			
a. Above waste	Control water influx	Groundwater flow	Yes
	Limit release of volatiles	Non-isothermal transport	No
b. Below waste	Limit contaminant transport in groundwater	Groundwater flow	Yes
		Contaminant retardation	No

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Step 5: Performance Goals and Confidences

In step 5, a value is assigned for each performance measure selected in step 4. This value is the goal whose achievement is expected to be demonstrated by the testing program and that will be used in preliminary assessments of remediation or disposal system performance. Also in step 5, a confidence judged to be needed to achieve reasonable assurance of compliance with the goal is assigned. This confidence is stated in quantitative terms if possible, or in qualitative terms if not. Achieving reasonable assurance of compliance with regulatory standards is a primary criterion for picking the values assigned as performance goals and confidences.

In setting the goals, an attempt should also be made to achieve redundancy for the barriers chosen in step 3, provided that redundancy is thought necessary for showing reasonable assurance in the compliance documentation. Unnecessary redundancy may increase the difficulty of documenting compliance, simply because it would require more testing and analysis than a well-thought-out design strategy would require.

The goals should be as simple to evaluate as possible. They should, for example, be chosen so that a testing program can show whether they have been achieved. A goal that no test can measure with adequate confidence in the time available is of little use. Further consideration of whether the goals are reasonable will occur in a later step of performance allocation, when they are compared with the expectations for proposed tests. However, step 5 is best completed by looking ahead to what the proposed tests can really accomplish.

The goals will probably be stated, at least in the early iterations of performance allocation, in terms of bounds on performance measures. For example, if "X" is a performance measure, its goal is likely to be stated in a form such as

$$X > \text{(some number)},$$

where the number is a value that is expected to contribute significantly to complying with the performance requirement to which the performance measure is attached.

One reason that bounding values are likely to be appropriate is that step 5, like step 3, will probably rely on bounding data. However, information derived from such data will likely be adequate to decide that a barrier will provide adequate protection if its performance is better than a specified bound.

Determining what confidence is needed to achieve a specific performance goal can be based on quantitative or qualitative analysis. The determination may simply reflect a consensus of professional judgment or bounding analyses. Whenever it is possible to base the assignments of needed confidences on statistical evaluations and sensitivity analyses, well defined confidence intervals and standard statistical parameters should be used.

For some performance measures, assignment of needed confidences might be in terms of confidences associated with different percentiles of a cumulative frequency distribution. For example, a choice might be made to associate the term "very high confidence" with the 5th percentile of a distribution--to require, for example, that 95% of of the parameter values be less than some specific value. The term "high confidence" might be associated with the 20th percentile and "medium confidence" with the 50th percentile. In making such a choice, the word "confidence" will not be used in the sense that standard statistical textbooks use it, but allocations like these can serve to communicate intentions about the relative importance of a parameter value to the regulatory authority, and to those personnel who will measure it. As shown by table A-1, in the column for step 5, separate listings are required to state the (1) goals and (2) needed confidences (C_d) for the performance measures listed in step 4.

Step 6: Parameter Needs

Most of the performance measures treated in steps 4 and 5 will not be directly measurable quantities. They can be expressed by an equation such as

$$\text{Performance measure} = f(P_1, P_2, \ldots\ldots, P_n),$$

where each "P" is a parameter. In step 6, each performance measure is translated into the parameters on which it depends. To do so requires the listing of three things: the parameters, the ranges of values that those parameters are expected to have, and the confidence with which the range of parameter values must be known. A separate listing for each of these three products of the step is shown in table A-1, in the column for step 6. The ranges of parameter values must be chosen so that they will produce an acceptable value for the performance measure--a value that complies with the goal established in step 5. Needed confidences must be assigned such that collectively they will produce the confidence needed for the performance goal. The assignment of confidences may be based on professional judgment, sensitivity studies, or statistical analyses.

For example, the hydraulic conductivity of an unsaturated soil increases as the moisture content of the soil and pressure head increases. If a performance goal has been assigned to hydraulic conductivity of a disposal site soil above the water table, goals and needed confidences are assigned in step 6 to maximum acceptable moisture content of the soil and pressure head.

Achieving high confidence for some parameters may require only low-precision measurements. If the goal for a parameter that appears in step 6 is well within the range of values that exist at the site, a low-cost measurement technique for which wide variance in measured values is inherent may be entirely adequate for showing that the goal has been achieved.

Step 7: Test Definitions

Step 7 will be completed as a part of the planning for data collection and analysis. For each parameter listed in step 6, a description of the test or series of tests that will measure the parameter is given. The description defines the test by specifying the locations from which samples will be taken, the numbers of measurements to be made, the scale of the measurements, and other details, as appropriate. The description also explains the relationships between the parameters actually measured in the test and the parameters listed in step 6. Such an explanation is necessary because some parameters listed in step 6 cannot actually be measured.

From this information, project design engineers and scientists will produce two major pieces of information for listing in step 7--the names of the measured parameters, and the precision and accuracy with which they can be measured. A separate column for each of these two products of the step is given in table A-1, step 7.

Step 8: Evaluation of Test Plans

Step 8 requires comparison of the parameter needs listed in step 6 and the test definitions listed in step 7. By comparing the two listings, decisions can be made for each parameter regarding the adequacy of the proposed tests in addressing the needs established in step 6 and the goals and confidences listed in step 5. In other words, determinations can be made of whether the collective results of the tests defined in step 7 can show that the goals and confidences established in step 5 have been achieved. If these comparisons show that the planned tests are indeed capable of providing for the needs that are listed in step 6, then it can be demonstrated that the test program is adequate.

If the tests do not appear to be adequate for achieving the requirements of steps 5 and 6, the process of performance allocation becomes iterative. Performance goals and needed confidences in step 5 might be reallocated if, for example, step 8 has shown that the parameter goals in step 6 are simply unrealistic and not attainable by a reasonable test program.

On the other hand, the test program might be revised to plan new, more elaborate tests or to delete tests that are not needed for achieving the goals established in step 5. A third choice might be to revise both the goals and the test plans. Whichever of these revisions are undertaken, the performance allocation must go back one or more steps and then proceed forward through the process to step 8.

As shown by the two columns for step 8 (table A-1), two kinds of evaluations are made of the proposed work: statements of the goals whose achievement the tests can evaluate and statements of the level of confidence the tests can achieve. For the work that is actually initiated, these goals and confidences must match or exceed those listed in step 5.

Step 8 is the principal tool for determining the final form of a test and analysis program. After the evaluations that contribute to step 8 have been finished, a defensible test program that can be expected to adequately document compliance with applicable regulations will have been identified.

Step 9: Test Integration

Step 9 is a final check to remove redundancy. After allocations for the performance requirements have been done, the list produced by steps 6 and 7 will probably contain duplications of parameters and tests. A single parameter may appear, for example, in the expressions for more than one performance measure or in the needs for more than one performance requirement. Usually, one of the several needs for a specific parameter will be more restrictive than the others. In step 9, therefore, only those tests are that are most restrictive are listed.

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1.0 INTRODUCTION

This report establishes the framework and describes the objectives, strategy, scope, and technical approach for evaluating quantitatively the long-term effects on the environment of actions proposed (Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Final Environmental Impact Statement (HDW-EIS) (DOE 1987)) for permanent cleanup and disposal of radioactive and associated chemical wastes. The wastes are from defense-related activities at the Hanford Site in Washington State.

Complex mechanisms of waste release and migration for large spatial and temporal scales require that these evaluations be made in part by computer-assisted simulations of the conditions and dynamic processes important to releases of contaminants from the wastes, and their transport to the accessible environment. Such quantitative evaluations are termed "performance assessments." The results of the evaluations will be used to guide work on engineered barriers and the collection of disposal site information, and to document the performance of specific disposal actions. The plans of this report will be complemented, as needed, by detailed plans specific to completing the tasks identified here.

This introductory section (1) states the objectives of performance assessment technology development and relates the reasons for using this technology, (2) discusses the strategy needed to implement the technology, and (3) describes the purpose and scope of this report.

1.1 OBJECTIVES OF PERFORMANCE ASSESSMENT

The role of performance assessment in the permanent disposal of defense-related wastes at the Hanford Site is to determine if the waste disposal systems (i.e., waste form, engineered barriers, and natural barriers) retard release and transport of contaminants to the accessible environment (see chapter 5.0 for definitions) sufficiently to comply with applicable environmental protection regulations. Collection of information and performance of analyses needed to make this determination will be guided by allocating goals for performance to components of the waste disposal system (appendix A) and determining whether those goals are likely to be achieved cost-effectively and with adequate confidence. Evaluation of which disposal actions to take will be by the process shown in figure 1.

The strategy depicted by figure 1 is in terms of the prerequisites for each part of the evaluation process, the bases for each major decision, and the alternatives for mitigating predicted failures. The figure shows how both the allocation of performance goals and needed confidences based on results of sensitivity analyses and professional judgment, and the evaluation of constructibility and cost-effectiveness determine which

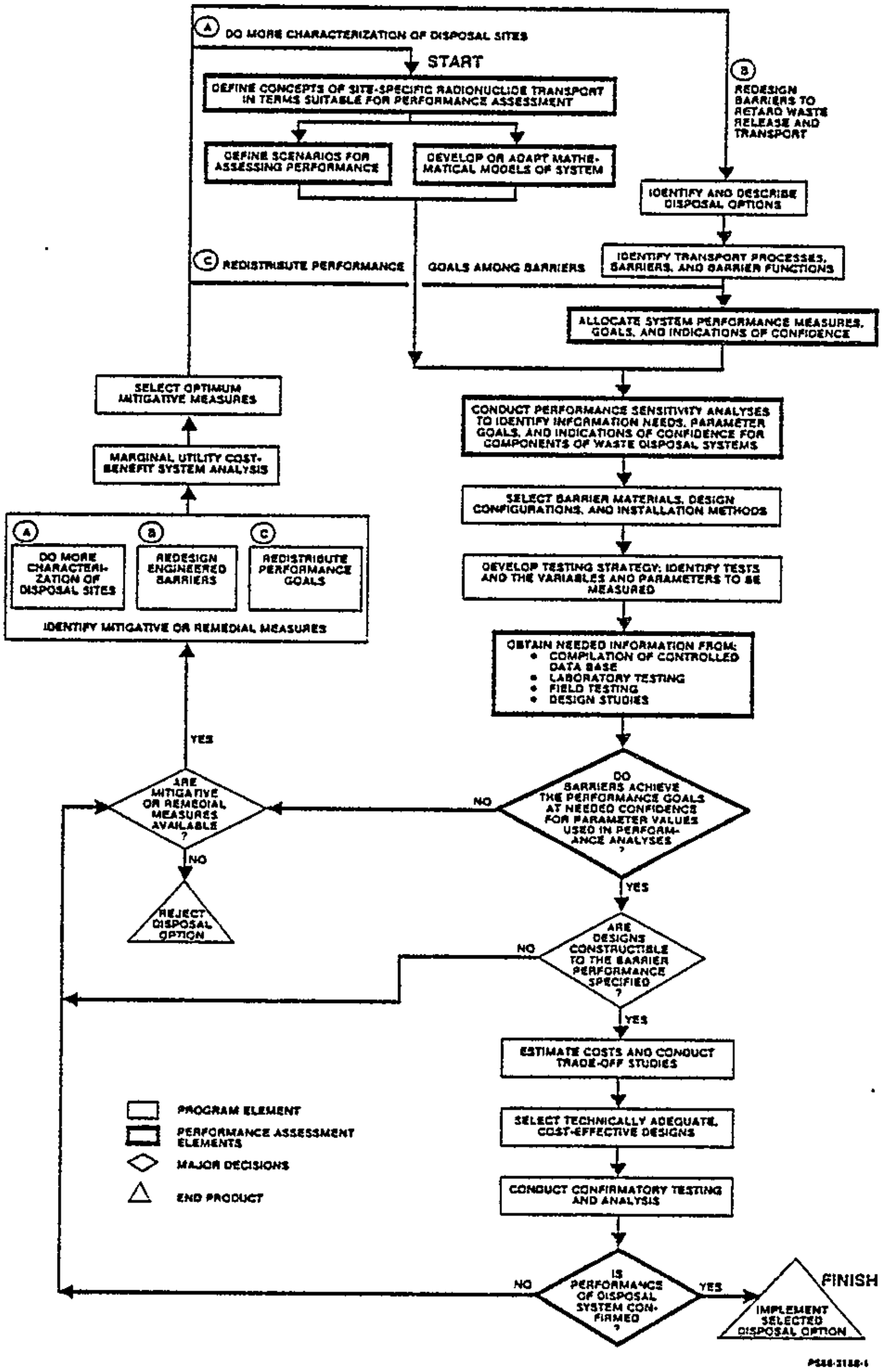

Figure 1. Use of Performance Assessment in Permanent Disposal of Wastes Generated by Defense Activities at the Hanford Site. (See chapter 5.0 for definition of terms; see text for explanation of specific activities.)

proposed activities will be initiated. Activities shown in the figure that are the direct purview of performance assessment (surrounded by a bold line) include the following:

- Define conceptual models, for expected and disruptive scenario (i.e., unexpected but credible) conditions, in terms that are suitable for assessing performance
- Develop computer-encoded mathematical models that quantitatively express the conceptual models in terms of contaminant release and transport processes, and the functioning of engineered and natural barriers
- Define system performance measures, and allocate performance goals and indications of confidence to help guide engineered barrier design and identify siting information needs
- Obtain and organize information needed for performance assessment from various internal and external sources
- Determine if specific natural and engineered barriers to contaminant release and migration achieve their performance goals with the confidence needed
- Predict the environmental effects that would result from the proposed waste disposal actions.

1.2 STRATEGY AND APPROACH

Because of the long-term risks associated with radioactive and hazardous chemical wastes, environmental protection regulations require that some evaluations of the acceptability of disposal systems consider durations of up to 10,000 yr. Because of these long durations and the complexity of the systems, computer-encoded mathematical models are well suited for simulating disposal system performance.

Some variables in the models may be expressed in terms of probability distributions to reflect uncertainties in the data characterizing the waste forms and disposal sites, performance of engineered barriers, model boundary conditions, and mathematical representations of system conditions and processes. Other variables will be expressed as discrete values or as conservatively assigned bounding ranges (i.e., assigned to accommodate the potential for a relatively large margin of error). The effectiveness of proposed waste disposal systems in retarding contaminant release and transport will be assessed by computing the rates of contaminant releases from proposed waste forms and the velocities of contaminant movement through each potentially significant transport pathway.

Performance assessment activities will help guide the work of the Hanford Site defense waste disposal program by (1) evaluating the relative sensitivity of system performance to specific contaminants, waste forms, barriers, and parameters, and (2) allocating numerical performance goals and needed confidences to specific components of waste disposal systems (appendix A). Acceptable values, ranges, or probability distributions will be assigned to parameters of contaminant release and transport, for each significant component of the system, such that, if they are achieved, the waste disposal action would comply with applicable regulations. By this means, decisions on the potential need for additional data, analysis, siting, and (or) design changes can be made and defended. Hence, as a consequence of performance assessment activities, the comparative merits of alternative waste disposal actions can be evaluated or confirmed, and siting or design features, site characterization information, or materials test data that are not needed to comply with performance goals can be identified (see fig. 1).

The focus of activities early in the performance assessment process is (1) development or adaptation of computer-encoded mathematical models, and (2) specification, based on expert judgment and results of sensitivity analyses, of data and data quality needed to adequately simulate disposal system performance. Collectively, the models will simulate release and transport of contaminants by processes dependent on the following site-specific features.

- <u>Climate</u>--The current and projected effects of climate on eolian erosion, evapotranspiration, and groundwater recharge.
- <u>Geology</u>--The effects on groundwater movement and contaminant transport of physical and chemical characteristics of soil and surficial sediments.
- <u>Hydrology</u>--The effects of groundwater chemistry and movement on contaminant release and transport.
- <u>Contaminant Source</u>--Waste-form chemistry, structure, and contaminant content.
- <u>Contaminant Release</u>--Rates and kinds of contaminant release from the waste-form; contaminant adsorption and desorption by soil and surficial sediments.
- <u>Contaminant Transport</u>--Rates and directions of advective and diffusive movement of contaminants.
- <u>Plant and Animal Contamination</u>--Ingestion of contaminants from water and food sources, evapotranspiration, and burrowing.
- <u>Scenarios</u>--Occurrence probabilities and consequences from disruptive natural events and human intrusion.

The complexity of specific performance assessments will depend on their purpose. It will also be a function of the complexity and assessed sensitivities of the site-specific conditions and processes considered, number and type of assumptions, amount and relative quality of available data, and the locations and configurations of the natural and engineered barriers. Consequently, the approach to assessing performance will likely be iterative. If confidence in the probability distribution functions, ranges, or specific values of modeling parameters increases because of design refinements and (or) collection of additional data, the confidence in performance predicted by the models will also increase. Thus, conceptual and mathematical models that are more complex than current models may eventually be justified as designs are refined and a more comprehensive data base becomes available.

Confidence in the accuracy of the simulations produced by a mathematical model is also governed by how well the conceptual model that is expressed by the mathematical model represents the actual system. The objective is to adequately represent the configurations, conditions, and processes of the system. However, the complexity of this representation is constrained by the mathematical model used. An ideal representation of a waste disposal system may require using stochastic variables to account for transient, three-dimensional, coupled processes operating in anisotropic, porous media. Existing computer codes cannot address all of these factors, nor is such capability required or cost-effective in achieving the needed confidence. Hence, the planned approach is to selectively improve, as needed, the capability of existing computer-encoded mathematical models to analyze those features to which system performance is most sensitive.

1.3 PURPOSE AND SCOPE OF THIS REPORT

This report consists of the plans for developing the strategy, framework, methods, and tools to evaluate the effectiveness of actions proposed to isolate defense-related radioactive and chemical wastes at the Hanford Site from the accessible environment. The wastes under consideration are described by the U.S. Department of Energy (DOE) in the HDW-EIS (DOE 1987).

The scope of this report is restricted to plans for developing analytical capabilities and the data base needed to adequately predict the (1) release and transport of contaminants in groundwater and (2) the resultant exposures of humans to such contaminants.

In the hierarchy of documents defining the program for disposal of defense-related radioactive and chemical wastes at the Hanford Site, this report is subordinate to the annually updated Hanford Waste Management Technology Plan (HWMTP) (DOE-RL 1987). Annually issued performance assessment technology program plans, topical reports on completed technology development studies, and reports on the results of specific performance assessments are subordinate to, and more narrow in scope than, this report (fig. 2).

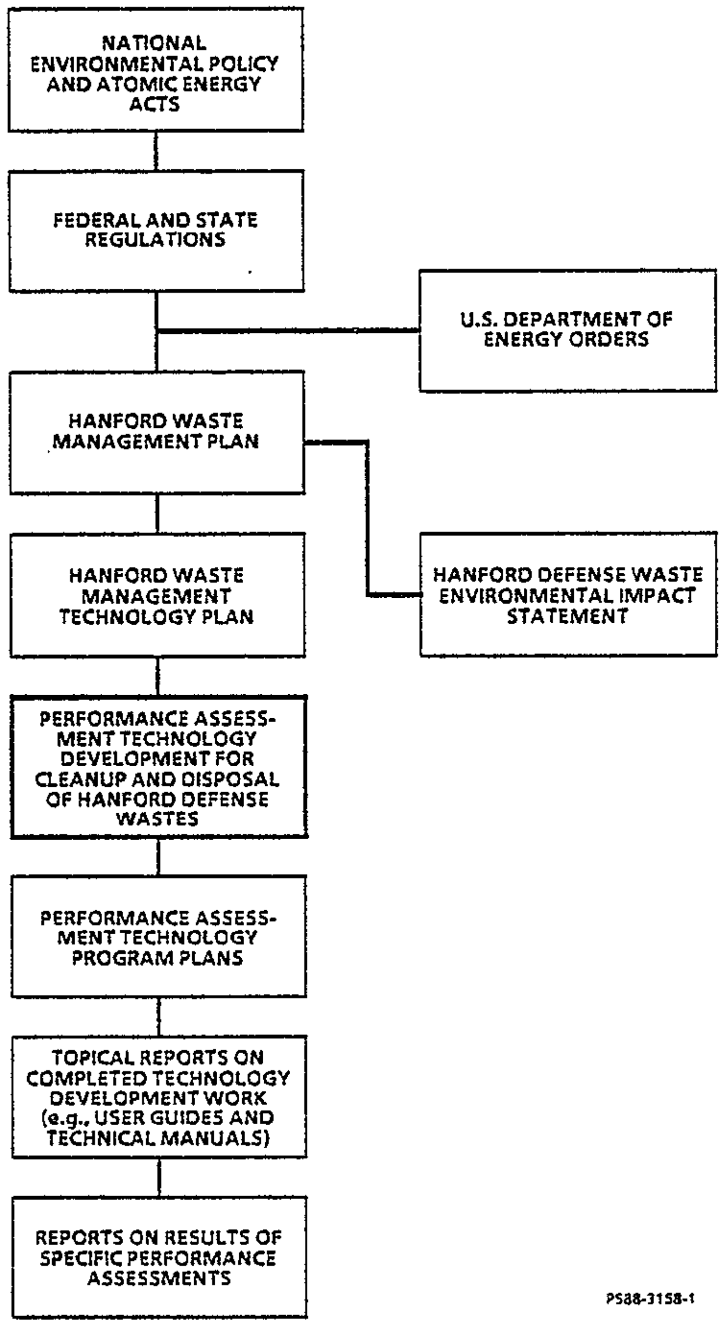

Figure 2. Hierarchy of Documents Controlling the Cleanup and Disposal of Wastes from Defense-Related Activities at the Hanford Site.

2.0 REGULATORY REQUIREMENTS AND PERFORMANCE ISSUES

As used in the context of this report, issues are technical questions that must be satisfactorily answered before the safety of a disposal action can be reasonably assured. The means for measuring the resolution of issues are criteria and standards that implement regulatory requirements: criteria are the types of measures; standards are the scales of measurement. Performance standards are the scales by which the results of performance assessments are measured to judge compliance with federal and state regulations.

Performance criteria and standards are the basis for the performance issues. Resolution of these issues, in turn, forms the basis for all performance assessment work. Consequently, the pertinent regulatory requirements, criteria, standards, and performance issues help form the basis of the plans that follow for developing performance assessment technology.

2.1 REGULATORY REQUIREMENTS AND U.S. DEPARTMENT OF ENERGY ORDERS

Regulatory requirements and DOE orders that are, or may be, pertinent as the basis for criteria and standards specific to disposal of hazardous chemical and radioactive wastes at the Hanford Site are given in chapter 6 of the HDW-EIS (DOE 1987).

2.2 PERFORMANCE ISSUES

Technical Issue DCS-1 of the HWMTP is stated (DOE-RL 1987) as follows:

> **What technology is required to credibly evaluate the effects on the environment of actions proposed for disposal of Hanford Site defense wastes? What additional technology or data base developments, if any, are needed to adequately determine that the actions taken will ensure that adverse health effects are as low as can reasonably be achieved?**

These questions can be answered most definitively for the contaminant release mechanism(s) and transport pathways for each waste form and disposal site, and for the processes and conditions envisioned during the time considered. Answers that help resolve this issue will be derived from the heirarchy of mathematical models used in the evaluation. For example, simulations of contaminant transport in groundwater are dependent on modeling of releases of contaminants from the waste forms and modeling of groundwater movement (fig. 3).

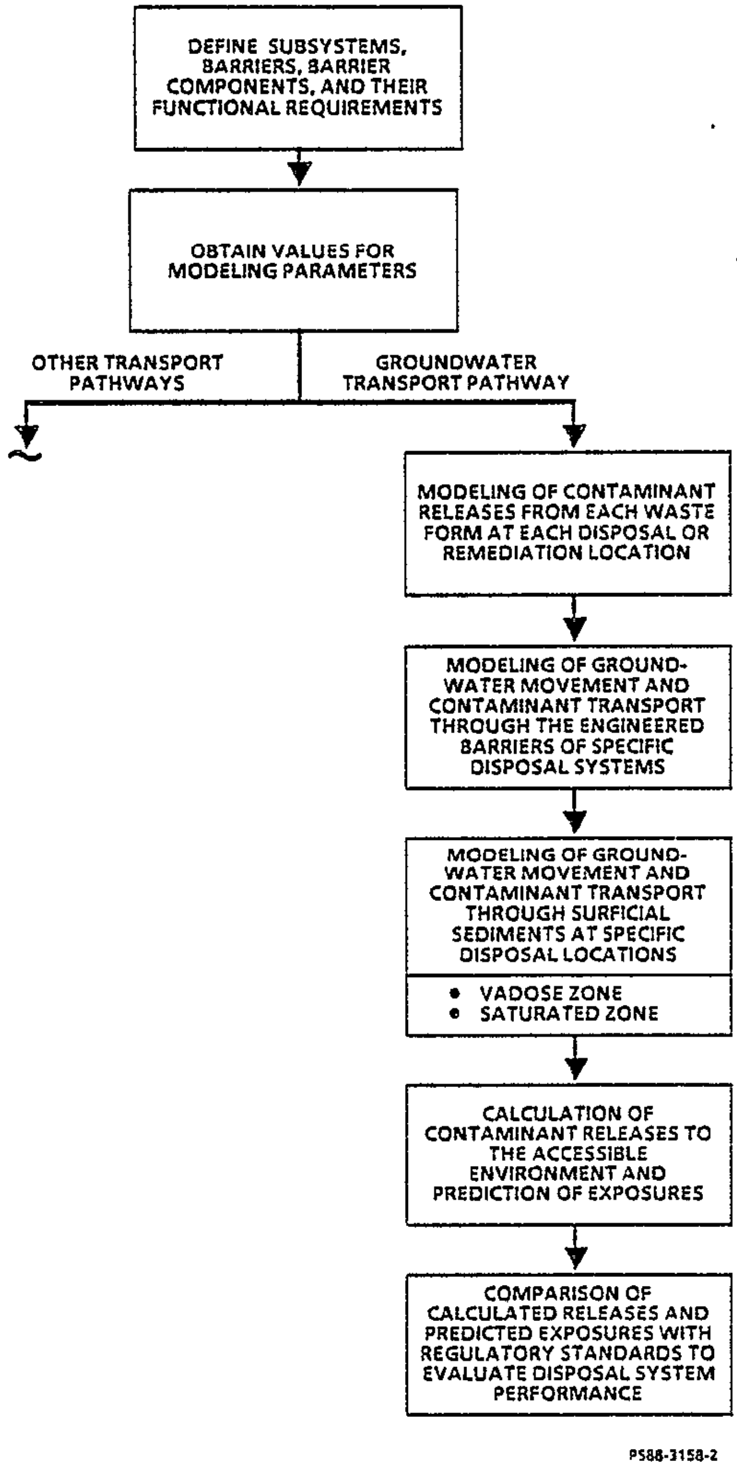

Figure 3. Simulation of Waste Disposal System Performance for the Groundwater Transport Pathway.

Several subordinate performance assessment issues can be identified that contribute to the resolution of Technical Issue DCS-1. For potential transport of contaminants to the accessible environment by groundwater, the following subissues are identified.

2.2.1 DCS-1A--Is the Modeling of Contaminant Releases from the Waste Forms Adequate?

1. What mathematical models will be used to simulate contaminant releases from each waste form at each disposal location?

2. Do those models need more development and, if so, what development?

3. What input data do the models require compared to data that are available?

2.2.2 DCS-1B--Is the Modeling of Groundwater Movement in the Vadose Zone and Unconfined Aquifer Adequate?

1. What mathematical models will be used to simulate vapor- and liquid-phase groundwater movement in the vadose zone and unconfined aquifer in the vicinity of each disposal location and for the Hanford Site as a whole?

2. Do those models need more development and, if so, what development?

3. What input data do the models require compared to data that are available?

2.2.3 DCS-1C--Is the Modeling of Contaminant Transport in Groundwater of the Vadose Zone and Unconfined Aquifer Adequate?

1. What mathematical models will be used to simulate groundwater transport of contaminants in the vadose zone and unconfined aquifer in the vicinity of each disposal location and for the Hanford Site as a whole?

2. Do those models need more development and, if so, what development?

3. What input data do the models require compared to data that are available?

2.2.4 DCS-1D--Is the Calculation of Human Exposures to Contaminants Resulting from the Waste Disposal Actions Adequate?

1. Are radiologic exposures to humans calculated in accordance with the latest approved methods of the International Council on Radiation Protection, and are exposures to hazardous chemicals calculated in accordance with current toxicology information?

2. If not, what additional development of the calculation method is needed to ensure accordance?

3. What input data are required compared to those that are available?

2.2.5 DCS-1E--Should the Modeling Methods be Capable of Analyzing Uncertainty? Are the Modeling Data in Terms of Probability Density Functions if Stochastic Modeling is Required?

1. Are stochastic versions of mathematical models needed for analysis of contaminant releases from the waste forms, groundwater movement, contaminant transport in groundwater, and calculation of resultant exposures to humans?

2. If so, what modifications of the deterministic models are needed and what input data do the models require compared to data that are available?

3.0 PLANS FOR COMPLETING TECHNOLOGY DEVELOPMENT TASKS

Twelve tasks have thus far been identified by the HWMTP (DOE-RL 1987) as requiring completion to adequately address Technical Issue DCS-1. Plans for work on three of these tasks relate to completing specific performance assessments for (1) disposal of wastes in grout, (2) developing performance criteria and standards, and (3) guiding barrier design. A fourth task, an assessment of performance of proposed waste disposal options for the HDW-EIS (DOE 1987), has been completed. These four tasks (DCS-1.2 through -1.5) are not the subject of this report.

The eight other tasks relate to development of performance assessment technology. Plans for completing these eight tasks are the subject of this report. Tasks to answer the questions of Technical Issue DCS-1 by addressing its five subordinate issues are identified, in part, based on results of the preliminary performance assessments for the HDW-EIS (DOE 1987).

3.1 IDENTIFICATION OF TASKS

The activities that are identified by the HWMTP (DOE-RL 1987), and the tasks comprising them that are identified by this report, are listed below (HWMTP activity numbers in parentheses; not necessarily listed in sequence of performance).

3.1.1 <u>Provide Program Development and Integration</u> (Activity DCS-1.1)

1. <u>Task DCS-1.1.1</u>--Establish an issues heirarchy that documents the relationships among performance issues, the data and analytical needs of design and performance assessment, and the work planned to fulfill those needs (completed, this report).

2. <u>Task DCS-1.1.2</u>--Develop a strategy, based on allocating performance goals and needed confidences (appendix A), for using performance assessment technology to evaluate the effectiveness of methods proposed to isolate contaminants from the accessible environment.

3. <u>Task DCS-1.1.3</u>--Develop conceptual models of the waste isolation systems that (a) account for groundwater movement, contaminant releases and transport, and human exposure for steady-state and transient conditions, and (b) are compatible with the detail of site-specific data, the capabilities of numerical models, and regulatory needs.

4. <u>Task DCS-1.1.4</u>--Identify what sensitivity analyses are needed to help allocate performance goals and assign needed confidences.

5. Task DCS-1.1.5--Identify priorities for collecting additional data and (or) developing analytical techniques, by allocating performance goals and assigning needed confidences to modeling parameters (appendix A).

6. Task DCS-1.1.6--Issue plans for improving the data base and (or) analytical capabilities, if these needs are indicated by the results of Task DCS-1.1.5.

7. Task DCS-1.1.7--Identify what performance assessments are needed for the permitting process, compliance with the National Environmental Policy Act, remedial investigations, feasibility studies, and other program needs.

8. Task DCS-1.1.8--Conduct and document independent peer reviews of performance assessment technology development work, and planned and completed sensitivity and performance assessment analyses.

3.1.2 Establish and Maintain a Data Base Suitable for Assessing Performance of Waste Disposal Options (Activity DCS-1.6)

1. Task DCS-1.6.1--Establish criteria and administrative procedures for determining and controlling the use of, and all changes or entries to, the performance assessment data base and the computer-encoded mathematical models used to process the data.

2. Task DCS-1.6.2--Establish and maintain a comprehensive data base and a controlled-entry archive of mathematical models for performance assessment. Include data on the waste types and inventories, mechanisms for release of contaminants from the waste forms, vadose and unconfined aquifer groundwater movement, and solubility and sorption parameters controlling radionuclide and chemical release and transport.

3.1.3 Ensure that Analyses of Contaminant Releases from the Waste Forms are Adequate (Activity DCS-1.7)

1. Task DCS-1.7.1--Develop or modify, establish benchmarks, calibrate, verify, and validate a computer-encoded mathematical model(s) that adequately predicts the rates of release of radionuclides and chemicals from the waste forms for steady-state and transient conditions.

2. Task DCS-1.7.2--Use the model(s) of Task DCS-1.7.1 to assess the sensitivity of waste-form performance to characteristics of disposal site, surficial sediments, and groundwater. Use the results of the sensitivity analyses to allocate performance goals and needed confidences (see fig. 1 and appendix A), and to provide source terms for the model(s) analyzing groundwater flow and contaminant transport.

3.1.4 Ensure that Analyses of Vadose Zone and Unconfined Aquifer Groundwater Movement are Adequate (Activity DCS-1.8)

1. Task DCS-1.8.1--Develop or modify, establish benchmarks, calibrate, verify, and validate a computer-encoded mathematical model(s) that adequately predicts groundwater movement in heterogeneous, hydrologically anisotropic surficial sediments of the vadose zone and unconfined aquifer for steady-state and transient conditions.

2. Task DCS-1.8.2--Use the model(s) of Task DCS-1.8.1 to assess the sensitivity of groundwater movement to characteristics of natural and engineered barriers of transport pathways. Use the results of the sensitivity analyses to allocate performance goals and needed confidences (see fig. 1 and appendix A) and to provide input for the model(s) analyzing contaminant transport.

3.1.5 Ensure that Analyses of Contaminant Transport by Groundwater of the Vadose Zone and Unconfined Aquifer are Adequate (Activity DCS-1.9)

1. Task DCS-1.9.1--Develop or modify, establish benchmarks, calibrate, verify, and validate a computer-encoded mathematical model(s) that adequately simulates contaminant transport by groundwater of the vadose zone and unconfined aquifer. The model(s) must be capable of addressing interactions between the contaminant and heterogeneous, anisotropic media through which the contaminant may migrate, for steady-state and transient conditions.

2. Task DCS-1.9.2--Use the model(s) of Task DCS-1.9.1 to assess the sensitivity of contaminant transport to variation of the parameter values that affect transport. Use the sensitivity analyses to allocate performance goals and needed confidences (see fig. 1 and appendix A), and to provide the source terms for the model(s) analyzing radiation and hazardous chemical exposure.

3.1.6 Ensure that Analyses of Human Exposures to Contaminants Resulting from the Waste Disposal Actions are Adequate (Activity DCS-1.10)

1. Task DCS-1.10.1--Develop or modify, establish benchmarks, calibrate, and verify a computer-encoded mathematical model(s) that adequately simulates exposures to radiation and (or) hazardous chemicals resulting from the waste disposal actions. The model(s) must calculate exposures to radiation in accordance with the latest methods of the International Council on Radiation Protection, and exposures to hazardous chemicals in accordance with current toxicology information.

2. Task DCS-1.10.2--Use the model(s) to assess the sensitivity of predicted exposures to radiation and chemicals. Use the sensitivity analyses to allocate performance goals and needed confidences (appendix A).

3.1.7 Develop the Capability to Analyze Uncertainty, if Required (Activity DCS-1.11)

1. Task DCS-1.11.1--Develop or modify, establish benchmarks, calibrate, verify, and validate stochastic versions of previously developed deterministic models, if required by regulatory agencies.

2. Task DCS-1.11.2--Obtain probability density functions for modeling parameters that require consideration of uncertainty, and document plans for stochastic analyses of the performance of specific waste disposal systems.

3.1.8 Develop and Implement a Performance Assessment Quality Assurance Plan (Activity DCS-1.12)

1. Task DCS-1.12.1--Develop a quality assurance plan that is sufficient in scope and detail to include development and use of the data base, conceptual models, and computer-encoded mathematical models used to predict performance of the proposed waste disposal actions.

2. Task DCS-1.12.2--Implement the quality assurance plan in a manner that documents the developing, documenting, calibrating, verifying, validating, and change control of the data base and mathematical models in accordance with Supplement 3S-1, NQA-1-1986 (ANSI/ASME 1986) and Silling (1983).

3.2 TASK PRIORITIES

There are two factors that determine when technology development work needed for performance assessment will be undertaken: (1) the critical-path sequence of information and analytical requirements of the performance assessment process (see fig. 1) and (2) funding availability. The first factor is a function of the sequential relationships in the process, current development level of the mathematical models and data (fig. 4), and the relative priorities of performance assessment information needs.

These task priorities and determination of modeling capabilities, compared to required capabilities, will be disclosed in detail by planned sensitivity analyses, peer review, and the allocation of performance goals and needed confidences to critical portions of the waste isolation systems (see fig. 4). For the interim, performance assessments for waste disposal options of the HDW-EIS (DOE 1987) provide initial guidance for setting priorities of future work.

The results of initial performance assessments (i.e., in the HDW-EIS) indicate that additional data collection and work on performance assessment technology are required to reduce uncertainties, assumptions, and simplifications in the current performance predictions. This additional work includes collation of existing data, collection of additional site-specific data, and efforts to ensure that the computer-encoded mathematical models used to make the predictions are verified, calibrated, and validated in accordance with approved quality assurance procedures before their use in assessing performance. Consequently, initiation of the additional work requires that an acceptable quality assurance program be in place, and an archive consisting of a controlled data base and functioning set of computer-encoded models be established.

3.3 DESCRIPTIONS OF TASKS

The descriptions of tasks in this section are ordered in terms of the required sequence of task performance (see fig. 4). Priority is reflected by schedule and funding; high-priority tasks are scheduled for completion earlier and receive priority funding. Tasks of essentially equal priority, or that must be performed in parallel, typically are evident from their location in figure 4.

The relative effort expended on a given task will in many cases be determined by the three major decision points shown in figure 4. Two decisions relate to whether additional development of deterministic and probabilistic computer-encoded models is needed. A third decision will answer the question of whether the results of completed performance analyses indicate a need for changes in engineered barrier designs and (or) collection of additional disposal or remediation site data, and (or)

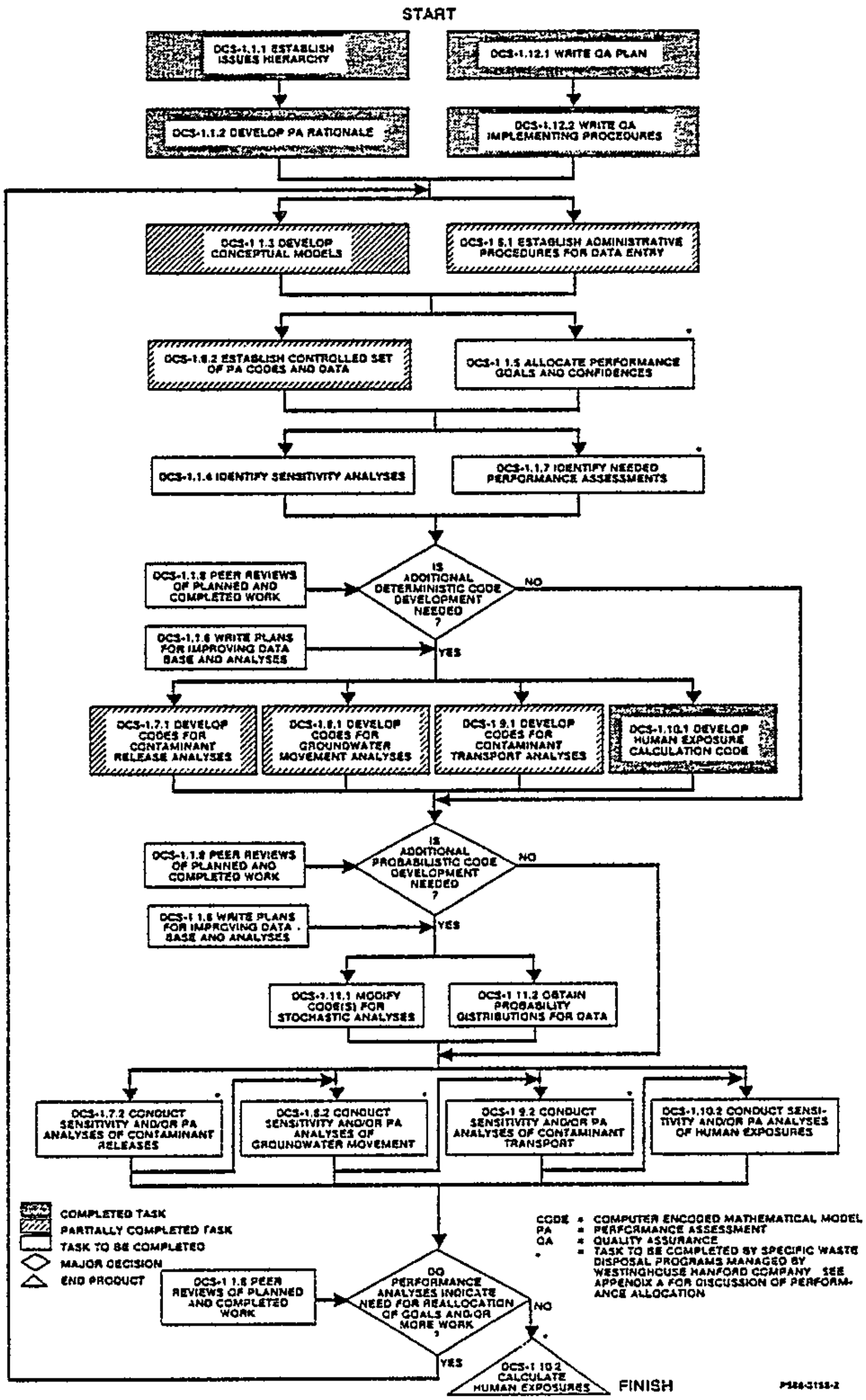

Figure 4. Relationship and Status of Performance Assessment Technology Development Tasks.

reallocation of performance goals among release and transport barriers (fig. 1 and appendix A). Consequently, current assignments of priority are subject to change pending the results of planned performance analyses, funding, regulatory guidance, and system design or siting changes.

The scope of this report is limited to planned performance assessment technology development; therefore, tasks shown in figure 4 as completed are not described in this section, nor are tasks that are the responsibility of other programs managed by Westinghouse Hanford Company (Westinghouse Hanford), except as they affect the tasks of the performance assessment technology development program.

3.3.1 Task DCS-1.1.1--Establish an Issues Heirarchy

(Completed; section 2.2 of this report.)

3.3.2 Task DCS-1.1.2--Develop a Strategy, Based on Issues and Allocation of Performance Goals, to Evaluate Waste Disposal Actions

(Completed; sections 1.1, 1.2, and appendix A of this report.)

3.3.3 Task DCS-1.12.1--Develop a Quality Assurance Plan for Performance Assessment

(Completed under subcontract to Pacific Northwest Laboratories (PNL) (1987).)

3.3.4 Task DCS-1.12.2--Issue Procedures to Implement Quality Assurance Plan

(Completed under subcontract to PNL (1987).)

3.3.5 Task DCS-1.1.3--Develop Concepts of Contaminant Release and Transport by Groundwater that are Suitable for Use in Performance Assessment

Conceptual models qualitatively describe waste disposal systems in terms of our understanding of their physical description and the processes and conditions governing their behavior. Conceptual models are based on design concepts and the accumulated body of knowledge about waste cleanup or disposal sites. Conceptual models usable for assessing performance describe the systems in terms appropriate for subsequent development of the computer-encoded mathematical models that quantitatively simulate system processes and conditions.

The objective of this task is to use current waste-form information, engineered subsystem designs, and data on the hydrogeologic characteristics of the waste disposal sites to develop integrated concepts of the physical characteristics and governing processes of the waste remediation or disposal system.

The scope of conceptual model development required by this task encompasses nominal (i.e., expected) and scenario (i.e., unexpected but credible) conditions and events during the next 10,000 yr. It additionally includes addressing the full range of uncertainties in parameters and conceptual models used in assessing performance for both nominal and scenario conditions and events. Development of conceptual models will be accomplished by completing the following work elements.

1. Identify mechanisms and processes affecting contaminant releases from the waste forms.

2. Delineate paths of contaminant migration in groundwater.

3. Identify processes, boundary conditions, and system characteristics that can be controlled by siting, barrier design, or material selections to inhibit contaminant releases and transport.

4. Identify dimensions of the conceptual model(s), configuration of its coordinates, and the geometry and dimensions of the system components in terms that are compatible with the preceding three elements.

5. Based on the results of the preceding four elements, make defensible simplifying assumptions to eliminate those features of the system that may be neglected without an unwarranted decrease in the conservatism of the analysis.

Of these five work elements, only 4 and 5 are currently within the direct purview of the performance assessment technology development program. Elements 1 through 3 are the responsibility of other defense waste management programs managed by Westinghouse Hanford. Elements 4 and 5 are required to make the conceptual models compatible with the level of complexity that can be numerically represented by computer-encoded mathematical models. Considerations for inclusion of a system characteristic in the mathematical models include sensitivity of performance to that characteristic and relative level of confidence in the ability to properly describe it.

Completion of this task will be documented by reports that describe the concept(s) of the disposal system for each waste form. These reports will be updated, as required, by the collection of additional waste form and disposal site information and refinement of engineered design concepts.

3.3.6 Task DCS-1.6.1--Establish Criteria and Procedures for Entering Information into a Performance Assessment Data Base

The objective of this task is to establish the criteria and implementing procedures for entering computer codes and data into a data base for simulating performance of waste disposal systems. Achieving this objective requires that the input data needed by each computer-encoded mathematical model be identified to ensure that the criteria for accepting data into a controlled data base are sufficiently specific.

Criteria for selecting data that are appropriate for assessing performance are likely to include applicability with reference to waste-form type and site-specific conditions, whether the data can be documented as having been collected in accordance with quality assurance and quality control procedures, and relative precision and accuracy compared to that required to achieve needed confidence. In any case, the criteria must comply with the provisions of NQA-1-1986, Supplement 3S-1 (ANSI/ASTM 1986).

Criteria for approval of computer codes to assess performance for documentation of compliance with regulatory requirements are likely to include demonstration that acceptable benchmarks have been established for the codes and that the codes have been adequately calibrated, verified, and validated. Criteria for approval of computer codes to evaluate the sensitivity of performance to variation in parameter values probably need not be as stringent as those for assessing performance for documenting compliance with applicable regulations. These criteria will, for example, include issuance of a user's manual, technical report, and preliminary verification and benchmark reports.

Appropriate administrative procedures are required to document that archived computer codes and data comply with applicable data base entry criteria, that changes made to update the codes and data also comply with the entry criteria, and that these changes are specified as either supercedent or supplemental. Completion of this task will be confirmed by issuance and approval of written criteria, and implementation of administrative procedures that document compliance with the criteria.

3.3.7 Task DCS-1.6.2--Establish and Maintain a Controlled Set of Computer-Encoded Mathematical Models, and a Data Base for the Models

The objective of this task is to establish an archive of computer codes and specify data approved for use in evaluating the sensitivity of performance to characteristics of system components and values of parameters, and in assessing system performance to document compliance with applicable regulations.

The archive established by this task must be enterable, and its contained information retrievable, by computer. Safeguards must be provided against unauthorized entry and changes. The hardware and software for data entry and retrieval must be easily accessible by terminals linked to the principal Hanford Site computer.

Completion of this task will be documented by a demonstrably operable data entry, storage, and retrieval system that is the depository of computer codes and data for assessing performance of Hanford Site defense waste disposal systems.

3.3.8 Task DCS-1.1.5--Allocate Performance Goals and Confidences to Identify Information Needs

(Task is to be performed by the Hanford Site Criteria and Standards Program managed by Westinghouse Hanford.)

Although this task is currently not the responsibility of performance assessment technology development, its dependence on the results of performance sensitivity analyses and its role in recommending future work require close cooperation with performance assessment activities. Preclusion of potential conflicts of interest likely will require that performance allocation be performed by organizations and personnel other than those that will perform the data collection work recommended as a result of the allocation process.

Performance goals for disruptive scenario conditions may differ from those assigned for expected conditions for several reasons. One reason is that the probability of occurrence of such scenarios is, by definition, comparatively low. Consequently, their effects on the probability distribution function for total (expected and scenario) cumulative releases of contaminants will be proportionally smaller than those for expected conditions. As a result, more latitude is likely to be appropriate in assigning performance goals for scenarios. A second reason is that the performance objectives for the low-probability portion of a cumulative probability distribution function will differ from those of the high-probability portion; larger releases (perhaps ten times larger) are likely to be allowable for low-probability scenarios. A third reason is that larger uncertainties are generally associated with disruptive scenarios than with expected conditions. Accordingly, the performance goals allocated for scenarios must address these larger uncertainties.

Performance allocation will likely be an iterative process. Consequently, periodic updates will be required in response to new disposal site data, design refinements, and results of updated sensitivity analyses. Completion of this task will require documentation of the type specified by appendix A; i.e., tables that interrelate system barriers and their functions, processes affecting contaminant transport, performance measures, and performance goals and needed confidences.